A STUDY OF AN ANT.

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The colonies of *Stenamma (Aphœnogaster) fulvum* Mayr, subspecies *aquira* Buckley, variety *piceum* Emery, a Myrmicid ant found commonly in the neighborhood of Wood's Hole have varied in the numbers of their inmates from a few individuals to many thousands. The nests are near the surface, in mellow soil, by roadsides, in meadows, and in woods, and are usually near, among, or under loose stones.[1]

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[1] Unless otherwise indicated the ants under observation were kept in the portable nests described by the author in Vol. 2, No. 2, of the *Biological Bulletin*. The species mentioned in this paper were identified for the writer by Prof. William Morton Wheeler, of the University of Texas. The colonies under inspection were kept at the Marine Biological Laboratory at Wood's Hole, Mass., from July to the end of September, 1900, and in New York City from then until the first of June, 1901, when they were carried back to Wood's Hole. The temperature of the room in which they were kept in New York varied from 40° to 90° F., or 5° to 35° C., and this variation often occurred during single days. The word *day* is used throughout this narrative as representing a period of twenty-four hours' duration. The use of Petri double-dishes in the study of living ants was suggested to the author by Prof. Wheeler. Those referred to in this study were about 100 millimeters in diameter and 10 mm. deep on the inside. The cell formed by the double dish was set upon a disk of cardboard, covered with white Turkish towelling, to which a tiny patch of black silk was attached. The Petri cell was set upon this disk, which was wider than itself, and the cell was covered with another disk of thick dark blotting paper. Within the cell were two sections of very fine-meshed sponge about 6 mm. thick, covering one-third the floor of the cell, and so placed as to leave a passageway for the ants between the sponge and the cell-wall, and also a triangular space where the ants could settle between the sponges and above the black patch. The sponges were kept saturated with water, to give drink to the ants and moisture to the air, and to prevent the hiding of the eggs in the interstices of the sponge. Care was taken that the sponges should not overflow and inundate the young.

Particles of food, from three to six kinds, known to be acceptable to the ants, were constantly provided, and laid on that part of the floor farthest from the sponges. The air, the water, and the food were kept always fresh and clean. The sponges, were dipped in alcohol and well rinsed once a week.

The cells were set upon the shelves of a dark, well-aired cupboard, with the food-side of the cell toward the source of light. Not more than seven ants were permanently housed in a single cell. Among the ants kept several months in this manner there were scarcely any deaths from natural causes,

The workers are brown in their general color, and are from four to seven millimeters in length, and, although they are apparently alike in all except size, they are here referred to as majors, minors and minims, the majors being from six to seven millimeters long, the minors from five to six, and the minims from four to five. When the colony moves the majors do the main part of the work of transporting the inert young, and they often seize, lift and carry to the new abode such ants as adhere too persistently to the old habitation. The minors appear to do a large part of the scouting and purveying. The minims are greatly devoted to the care of the eggs, larvæ and pupæ. All assiduously serve the queen, and all engage in battles with enemies.

The queens are from seven to eight millimeters in length without their wings, and are redder than the workers. The kings are from six to seven millimeters long, with the wings projecting another millimeter beyond the end of the body, and are jet black in color.

The workers are efficient fighters, and at close quarters will kill *Formica fusca*, double their bulk. They evince extreme hostility not only to ants of other species, but to those of other or alien colonies of their own species and variety. In this paper the term *alien* is used to denote a different colony of the same species and variety. Queens of different colonies, when placed together in a nest or a Petri cell, ostracize each other, remaining as far apart as possible. If forced into close quarters, they interlock mandibles and push and pull one another until one dies. An alien queen, introduced into and unable to flee from a queenless colony, is attacked by its workers, and though she may make a brave fight, is eventually killed. When a queen is alone she will sometimes fight in defense

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and after a day or two of quiet residence in this abode they showed little disposition to leave it, but carried on their normal occupations with an appearance of contentment.

In cleaning the cell, the cover was gently removed in a dim light, the left hand was placed snugly over the part of the cell occupied by the ant family, and the ants stayed in the agreeable warmth and darkness thus provided for them while the unoccupied part of the cell was cleaned. By externally covering any portion of the cell floor with the black patch, and setting the cell in a dim light, the ants were made to move to the selected site without serious disturbance or loss of eggs.

For prolonged observation of the ants I used a weak light, natural or artificial, hand lenses, and a background, under the glass floor, of whatever color best showed the object.

of her eggs, larvæ and pupæ; but if there be workers belonging to her, she retires to a place of safety, and remains there until the fracas subsides and the workers seek her out.

Workers from different colonies shut into the same nest will fight until but one party remains. I put into a Janet nest, which one colony had occupied for a week, another colony that had for two weeks been in a Lubbock nest. The following day the Lubbock colony was congregated with a mass of its young in three stages in the food-room; the Janet colony was likewise congregated with its young in the adjoining nursery, and a battle was raging between groups of two, of three, of four and of five, the attacks being always upon single ants. A day later eighty ants had been slain, and the warfare continued. On the fifth day the young of both colonies had all been brought together into the nursery and the victorious remnant of the Janet colony was alone with its spoils.

When a single alien *Stenamma fulvum piceum* is introduced into a colony, it at once exhibits signs of terror, endeavors to flee or to hide, and keeps apart from the habitants; but sooner or later an inmate comes upon it, and though it may slay its opponent in a duel or two, it is sure to be destroyed, as no *Stenamma fulvum piceum* code of honor intervenes against an attack of many upon one.

Long-continued isolation does not abate the hostility of *Stenamma fulvum piceum* to an alien. I have tried many experiments with queens that had lived solitary for several months, introducing to their respective domiciles alien workers of all ages, from long mature adults to callows just beginning to walk, and I have but rarely succeeded in effecting a reconciliation between the two. The hostility of the worker to the queen was usually as marked as was that of the queen to the worker. The few cases in which affiliation was induced were all between the queen and very young callows, whose impudence appears sometimes to be condoned by their elders. An instance of this toleration was given by a queen and one major worker that had been isolated in a Petri cell for more than three months. After killing several older callows, introduced one by one, they had permitted an alien minim, introduced when but a few hours old, to remain with them. Five days later I introduced two sisters of their adopted young worker, the newcomers being minims about twenty days old. These newcomers

at once attacked the queen and the major. The major acted solely on the defensive. Curling her abdomen in, and sitting on the small of her back, with her tough thorax presented to her small enemy, she permitted much nabbing of her body and much pulling of her limbs, making no retaliation. The queen, on her part, caught her little adversary by its antenna and held it firmly and quietly for some minutes, then released it and stood head to head with it without nipping it. The whole conduct of the adults was like that often seen in big dogs that are playing with obstreperous puppies. It appeared as if the adults liked their adopted callow and were unwilling to harm its sisters. The three callows perfectly affiliated from the start; but the newcomers often renewed their attacks on the queen and the major, and after some hours were killed by the adults. The adopted callow continued to live in that cell.

The kings of different colonies are indifferent or friendly to one another, and they have no steady foes either in their own or other households of their kind. They are the only active representatives of their colony that are ever cordially received in any other colony, and strong inducements are apparently offered for their permanent residence among the aliens. I have seen two workers, one on either side of an alien king, holding to his wings and gently conducting him through the grass to the entrance of their domicile; and I have repeatedly seen the workers capture, lift and carry alien kings home with them. If, about swarming time, an alien king is dropped into one of my glass nests, the workers seize him by his wings and forcibly detain him among them. If he later wanders away, they follow, lift and bring him back. The kings are much petted by the workers; their bodies are licked clean, their wings are straightened and smoothed, and their heads are patted with the antennæ. If the colony is forced to change its place of residence the kings are picked up by the small of the back and carried to the new abode. Young winged queens manifest great friendliness toward alien kings. Probably cross-fertilization is common if not universal.

Stenamma fulvum piceum of the same colony, queens, kings and workers, generally live amicably together. The queen is followed, tended, licked and patted, and is the evident centre of attraction in the group.

Colonies captured and confined in my nests just before swarming time, within a few days divided into as many groups as there were queens, the queens disposing themselves as far apart as the limits of the nest permitted. When a queen was then removed by me, the workers at once carried the young and settled down by another queen.

A wingless queen, after wandering for some days alone in a Lubbock nest, cleared an irregularly oval space about three centimeters long and two centimeters wide, building a smooth solid wall with the particles of earth that she removed from her floor. The wall was compact and vertical, and for more than half the circumference of the structure extended a distance of five millimeters from the floor to the glass roof. She worked industriously for several days on this structure and then laid an egg, which she lifted and carried between her mandibles whenever light was admitted to her dwelling. The day after the laying of the first egg, a visitor lifted the glass roof of the nest and spoiled her work. I then marked her, using a fine camel's-hair brush and dotting the top of her abdomen with a fleck of quickly drying varnish into which water colors had been rubbed, and I then returned her to her own colony, from which she had been absent three weeks. The first worker that she there met stood head to head with her for some minutes, while the two tapped each other with antennæ and the worker regurgitated food to the queen. Other ants greeted her with the same ordinary signs of satisfaction. Nine queens taken on their emergence from the nest at swarming in September and placed in Petri cells, each with an alien king, retained their wings from two to three months, and only one of them laid eggs before shedding her wings. One of my queens shed her wings the day she was captured, and another retained hers nearly four months. One laid her first egg twenty-seven days after swarming in September, and one laid no eggs until January, one hundred and six days after swarming. None of the score of queens that I have isolated at their swarming with alien kings has failed sooner or later to lay eggs.

The eggs are deposited one at a time, without regularity in the intervals. Only once have I known so many as six to be deposited in a single day, one or two a day being the ordinary number. If the queen is agitated or troubled she ceases from egg-laying, some-

times for many days together. Some of the queens in my Petri cells have averaged more than one egg a day during every month from September to the following July, and they and their workers appear to be in good health, though they have had during the winter no respite from the labor of rearing the young.

The eggs laid by the queens are visible to the unassisted eye, are a pearly translucent white, and are oblong in shape, the thickness being about half the length, which is half a millimeter. When the queen is about to deposit an egg, workers stand about her, as if aware of a new duty, and they pick up the egg as soon as it is deposited and add it to the packet, which is constantly tended, kept clean, watched over and carried about by the workers. The egg-packet, after being carried about for some time by one worker, is passed over to another, who appears to assume the burden eagerly. If the queen is alone she takes care of her own eggs.

In order to ascertain the time of incubation, I placed queens each in a clean Petri cell, some with workers, some without workers, and cleaned each cell daily until the first egg was deposited in it. I examined the cell two or three times a day, and recorded the time of deposit of the first egg and of a few succeeding ones. In some cases I removed the queen after a few eggs had been deposited, leaving the eggs to the care of the workers alone. I counted the eggs daily to see that there was no diminution in their number, and I cast out from my calculations all cases in which there was a diminution of the number of eggs during the time of my observations. I was also careful that there should be no manipulation nor disturbance of the eggs except by the ants themselves. The eggs recorded were laid between the 7th of October and the 8th of the following May, and were laid by ten different queens. Twenty-two simultaneous or successive broods were thus observed, with the result that in two cases the first larva appeared on the eighteenth day after the laying of the first egg; in nine cases on the nineteenth day; in ten cases on the twentieth day; in one case on the twenty-first day. The time of incubation was not influenced solely by temperature, for eggs laid by different queens on the same day did not invariably hatch on the same day. In six of the twenty-two broods two eggs were deposited by the same queen on the first day, and these six broods each produced its first two larvæ within the same day. Furthermore, the appearance of

larvæ succeeding the first in each brood corresponded closely with the times of the deposit of eggs succeeding the first laid. Various broods, removed to weak alcohol or hot water and examined under a lens, showed the larva well formed in the egg at about the seventeenth day and no earlier. Broods in which the first larva appeared on the nineteenth day were immersed in alcohol and examined under a lens, and they always showed earlier, but never later, stages of larval existence; while broods in which no larva had appeared on the twentieth day showed, when examined in like manner, a larva perfectly formed within the egg membrane. I therefore conclude that the period of incubation varies between seventeen and twenty-two days, with nineteen days as the common period. The variation in the period of incubation bears no fixed relation to the size of the future adult. Eggs of different periods of incubation followed to the adult form were found to produce the same sort of worker.

My ants have furnished no evidence that they ever devour the eggs, larvæ or pupæ of their own colony. One worker, isolated in a Petri cell twenty-one days without food, died leaving five eggs intact during the last sixteen days of her starvation. In all the score of Petri cells in which I have for months watched the condition and counted the numbers of the eggs, no diminution of them could be logically charged to the mature ants, whose skill and diligence in keeping them clean, safe, dry and in humid darkness, merits high renown.

The feeding of the larva, which is bent nearly double in the egg, with regurgitated food begins as soon as it straightens itself and protrudes its mouth. When the larvæ begin to appear in the egg-packet, the workers lift the packet and hold it free and still, while one of their number holds a translucent white globule of regurgitated food to the larval mouth projecting from the surface of the egg-packet. I have repeatedly seen the workers thus feeding the very young larvæ, a single globule of regurgitated food serving for a meal of which four or five larvæ successively partook.

When the larva first emerges, its length is nearly double that of the egg. When well fed its growth is rapid and in a day or two its length is three or four times that of the egg. When about two millimeters long it is usually removed from the egg-packet and laid on the floor, or associated with others of its size in a

separate bundle, the individuals being fastened together by the hooks on their surfaces, as the eggs were by their sticky shells. The habit which is observable in *Stenamma fulvum piceum*, in common with some other species of ants, of assorting the young in accordance with the size and form, doubtless economizes labor and also tends to the preservation of the young. The flexible neck of the larva enables it to reach to a distance equal to a quarter of its body-length, and to fix its mouth upon anything edible that is within its reach. I have observed a gradual diminution of the eggs in every cell where the smallness of the working force prevented that segregation of the larvæ and that assortment according to size which prevails in large communities; and I have also, in such circumstances, seen full-grown larvæ, and even pupæ, fall victims to the voracity of the unfed younger larvæ.

The older larvæ are often fed when lying upon their backs, the ventral side serving as a place of deposit for food reached by the curving of the neck, as described for *Ponera coarctata* by Prof. Wheeler in the *Biological Bulletin*, Vol. 2, No. 2. But this feeding posture is with *Stenamma fulvum piceum* scarcely more common than are others. Sometimes one larva is used as a table, not only for its own feeding, but for the feeding of two or three other larvæ that are inclined against its sides to take their portion of the same morsel. I have also seen five larvæ set on end around half the abdomen of a bisected house-fly, feeding voraciously from its interior, like pigs around a trough. Sometimes the larva is laid with its ventral side against a succulent portion of the insect, and is left there to take its fill; sometimes it has a portion of meat held to its mouth and forcibly removed as soon as it has had a brief repast, and sometimes a worker stands with her head over that of the larva and allows it to take food from her crop in a manner resembling that in which a mother-pigeon feeds her young. In my nests the very young larvæ have been fed solely upon regurgitated food. The older larvæ have been given particles of flies, mealworms, roaches, beetles, spiders, sponge-cake, white bread moistened with sweetened water, and of dried yolk of hens' eggs. They have also fed upon fragments of ants of other species, on pupæ of alien colonies, and on the pupæ and larvæ of *Cremastogaster lineolata* and of *Lasius umbratus*.

Larvæ deprived wholly of insect food did not during a period of

one hundred days produce one pupa. But larvæ grew from the egg to nearly full size without insect food, and one pupa, that later on became a minim, had no insect food during the last twenty-two days of its larval stage. The adult ants appear able to live on indefinitely without insect food; but there is a noticeable diminution in the number of eggs laid by the queen, and in the number of the larvæ simultaneously fed by the workers. I have seen no instance of the eating of members of their own colony by these ants, nor of their feeding their larvæ upon dismembered kin. But they will eat and feed to their larvæ the flesh of dismembered alien callows, and probably thickness of integument is all that protects alien adults from being commonly used as food.

The responsibility taken by the workers in the care of the young may have brought about an incapacity on the part of some of the queens to regurgitate food, and may have disabled them for solitary rearing of the larvæ.

Two sister queens that were taken at swarming on September 17, lived each with a king of another colony until the death of both kings, when I placed them, on November 13, together without workers in a Petri cell where they lived until the following June. The first egg was laid on December 8, and the first larva appeared on December 28, when there were fifteen eggs, cared for by both queens. The queens continued to lay eggs, and young larvæ frequently appeared among the eggs, but no larva lived longer than two or three days. Up to April 28, four months after the appearance of the first larva, no larva had been reared in this cell, although more than one brood had meantime been successfully reared in all similar cells where the queens were assisted by workers. I then thoroughly cleaned the cell and replaced the two queens. That same evening two eggs were deposited, and when, on May 7, the eggs had been increased to eleven, I put in two full-grown alien larvæ, and later on a white pupa, all of which were accepted by the queens. On May 24 the pupa became a minor ant, and at once began to assist the queens in the care of the eggs. On May 25 two new larvæ were to be seen among the eggs, and these larvæ continued to grow and live. The two introduced larvæ also thrived, and on June 10 the two queens and three callows were together engaged in tending a promising group of larvæ, the first that were reared from eggs in this cell.

Three solitary widowed queens of the five in my Petri cells, during four or more months after beginning to lay eggs, failed to rear any larvæ, although other queens to the number of seven, at the same time and in exactly similar conditions, with the exception of having worker-assistants, all reared one or more broods. The fourth solitary queen brought up a single male, I myself having given her much help in the feeding of one larva, the sole survivor among many that appeared and perished during four months. The fifth solitary queen had the assistance of workers in rearing her first larvæ, and later on when the workers were removed, she indisputably fed and reared larvæ all the way from the egg upward.

The length of the larval period has, in my nests of *Stenamma fulvum piceum*, as is generally thought to be the case with other ants, been apparently dependent on the amount and quality of the food-supply. Between October 27 and May 9 I recorded the beginning and end of the larval stage of twenty-six larvæ from queens' eggs. There was one of twenty days, one of twenty-one, one of twenty-two, three of twenty-four, one of twenty-five, one of twenty-six, one of twenty-seven, four of twenty-eight, one of twenty-nine, three of thirty, one of thirty-one, two of forty-two, one of fifty-three, one of eighty-four, three of ninety-three, and one of ninety-seven days' duration. All the larval periods shorter than forty-three days were in domiciles where the queen was present, and all over forty-three days were in cells where the larvæ were reared by workers alone. The assiduity of the worker is even obviously greater when the queen is present. The shortest period recorded was that of the larva in whose feeding I myself assisted the queen.

The length of the larval period does not determine the sex nor the size of the ant. In the cases above recorded, one larva having a period of twenty, one of thirty and one of ninety-three days all ultimately became males. One larva with a period of twenty-four, one of ninety-three and one of ninety-seven days all ultimately became minims. The only queen hatched in my nests had a larval period of fifty-three days. A queens'-egg-larva now under the care of three workers in one of my Petri cells has been in the larval stage a hundred and forty days.

From four to eight days previous to emergence from the larval

stage, the larva expels the contents of the alimentary canal, ceases to feed, and changes in color from translucent white with a brown core to creamy and more opaque white. Deprivation of food for some days will cause any half-grown larva to make these preparations for becoming a pupa, and minims can be reared at will.

The larvæ are kept resplendently clean by the licking given by the workers. In my nests the workers appeared to learn a use for the sponge, and when I at various times soiled a larva with stale insect juices, they rubbed it upon the sponge to clean away what they apparently disliked to lick off.

Either majors, minors, or minims alone can feed larvæ, but in my Petri cells, where food is always near, they have rarely reared more than three larvæ to each adult worker. A minim alone with a queen reared three larvæ simultaneously, and five majors together reared sixteen. The anxiety which impels the nurses to lift the immature young whenever the cell is uncovered probably hinders their rearing large numbers in these abodes. When disturbed, the workers first lift the oldest in the nest, the pupæ, the larvæ or the egg-packet. This order is also followed by the solitary queens.

After the larvæ are large enough to be removed from among the eggs of a packet and to lie separately on the floor, they are so fed as to bring them to about the same size. As the eggs are laid rather regularly, one or two a day, and are nearly equal in their periods of incubation, the larvæ, if evenly fed, would reach the pupa stage one by one. But great natural possibilities of shortening or prolonging the larval period by increase or diminution of the supplied nutriment, and the method of feeding the larvæ so unequally as to keep them nearly equal in size, causes the normal nest to be at times without pupæ, and at times to be destitute of advanced larvæ. I have observed in natural nests, and also in my artificial nests, that at times there are a great number of larvæ and no pupæ, and at times countless pupæ with no advanced larvæ.

The larvæ grow to the length of the pupæ perfected within their integument, varying from two to five millimeters. When the thin, transparent-white integument bursts, the ants clean the snow-white naked pupa, and constantly watch over and tend it. Its first color appears in the eye-spots, which are grayish on the third day and brown on the fifth. On the tenth day, with the utmost regularity,

there is a deposit of pigment on the dorsal side of the largest segments of the abdomen, and this color spreads and deepens until, on the twelfth day, the sex of the future ant can thereby be foretold, the worker-pupa being yellowish all over, the male-pupa gray-bodied with white limbs, the queen-pupa mottled brown and orange with yellowish limbs. Two days later the worker-pupa acquires the rich dark amber color which it retains as a callow; the slate color of the male-pupa deepens to black, and the queen-pupa has the tints of an adult queen. The length of the pupa-stage was ascertained by me for seventy-three pupa, all presumably the issue of queens' eggs, in fifteen different habitations, between January 5 and May 27. I took the time from emergence from the larval sheath to the assumption of the standing posture as the period of pupa-existence. Forty-four of my number proved to be minims, and of these two became such on the fourteenth day, twenty-three on the fifteenth day, and nineteen on the sixteenth day.

Fourteen became minors, and of these eleven became such on the seventeenth day and three on the eighteenth day.

Ten became majors, and of these five became such on the nineteenth day, four on the twentieth day and one on the twenty-first day.

The pupa-stage of the sixty-eight workers varied, therefore, between thirteen and twenty-two full days; but the minims may be said to have a pupa-period of about fifteen days, the minors a pupa-period of about seventeen days, and the majors a pupa-period of about nineteen days.

Four of the seventy-three pupæ became kings, and of these one became such on the eighteenth day, two on the nineteenth day and one on the twentieth day.

One only became a queen. She was a pupa nearly seventeen days, and died soon after beginning to walk about among the three workers that reared her from a queen's egg.

Of some hundreds of larvæ that have successfully been reared to the pupa-stage by my captive ants, not more than ten have failed to safely pass the pupa-stage and to live on as ants. The small proportion of deaths among the ant-children, in so unnatural an environment as is created by a glass nest and a human purveyor, surely indicates a more than human skill on the part of the

adults in their care of the offspring, or else wonderful tenacity of life on the part of the young ants.

The workers care for the pupæ with the same assiduity that distinguishes their attention to the eggs and the larvæ, but this attention does not appear to be necessary to the survival of the pupæ. I isolated ten pupæ in a Petri cell, having the same warmth, moisture, and general environment as had those pupæ remaining under the care of the workers, and although half of them were taken from their nurses before any color had been deposited in their integuments, every one of them came safely to the adult-stage. When, as callows, they were one by one returned to their adult kin, they received such an extraordinary amount of licking as to suggest the well-known theory that the pupæ exude a substance which is liked by the ants, and that the attention of the latter to the pupæ is not wholly altruistic.

These ants are very cleanly. In every nest where I have long kept them they have chosen a fixed place for the throwing of refuse, as remote as possible from the inert young.

They carry morsels of food and lay them on the sponges, as if with intent to moisten edibles that are too dry for their eating.

They follow their usual occupations both by day and by night. Individual ants rest sometimes for hours, standing motionless and apparently asleep. I have seen a worker spend more than an hour upon her toilet, combing or licking every part of her body as far as she could reach. Much willing service is renderd by the adults to each other in the cleaning of their integuments. I saw one worker hold another by a foot, apparently insisting upon such service, which was rendered at intervals and was renewed only when a limb was again nipped, during forty minutes. On the final release of the operator the two ants turned mouth to mouth and one regurgitated food to the other.

The muscular endurance of these ants seems to be great. They will fight with no cessation during several hours, holding an enemy by a limb or mandible. When the fight is a duel, the stronger ant, or the ant that first succeeds in nipping a leg or an antenna, thereby drags its opponent over objects, itself keeping the higher ground, until the limb is severed. In the Lubbock nests, the stronger fighter always threw the weaker into the moat, either before or after the death of the unfortunate. When a battleground

presents a precipice, the attempt to push the enemy over it is always noticeable. The successful use of the sting does not appear to be fatal to an ant-enemy, although it gives pain in the human hand for an hour or more.

Notwithstanding the general harmony and mutual helpfulness in a colony of *Stenamma fulvum piceum*, the ants have their individual quarrels. Three queens had lived by themselves serenely in a Petri cell for five months, giving common care for four months to their single group of eggs, when two of the queens began a tug of war, standing head to head, one holding the other by a mandible, and dragging or pushing her over and around the sponges. Uncovering the cell, watering the sponges, introducing an alien worker caused no cessation of the fray. The third queen, distinguished from the other two by a fragment of wing on one side, made frequent excursions to inspect the two belligerents, and then returned quickly to continue her care of the eggs. The battle persisted, with brief intervals, for four days, and then one of the two combatants was left on the side of the cell opposite the eggs, and there she remained in isolation for the ensuing ten days. I several times lifted her and placed her close to the other two queens and the eggs, but every time her wingless enemy seized her by the small of her back, carried her across the cell, and cast her down in the place for refuse, or else attacked and drove her back to her place of banishment. On the eleventh day the banished queen was permitted to return to her two sister queens and the eggs, but she died on the following afternoon.

One who watches the proceedings of these ants through many months finds numerous occasions when the sequence of events strongly suggests a designed punishment of individual offenders in the colony. Twice I have seen an assembly of older ants, its members ranged at nearly equal distances, forming a circle with all heads toward the centre, remaining motionless except in vibrations of the antennæ or a curious shaking of the abdomen, certainly for some hours, and probably for some days. These assemblages were each succeeded by an execution. In the one case an ant was torn asunder and cast in the kitchen-midden. In the other case one ant was dismembered, and another ant picked up the head and thorax of the dismembered victim and carried it about in the food-room. She was carrying it at all the many times when I looked

at her during the succeeding three days. Of course, the sequences noted may have been merely double coincidences in two unusual proceedings of the ants.

Both majors and minors among the *Stenamma fulvum piceum* sometimes lay eggs, especially when no queen is present in their habitation. The number of eggs laid is sometimes considerable. I have seen as many as three hundred at once in a nest of fifty workers from which a queen had been for several months absent. One of my Petri cells, in which the eggs of five isolated workers came to the larval stage, indicated that the time of incubation of these eggs may be the same as for queens' eggs, eighteen or nineteen days. The first egg was laid on February 21, the second on February 23, and the eggs were gradually increased to ten. The first larva appeared on the 12th and the second on the 14th of March.

The larval period of workers'-egg-larvæ under the care of workers alone, appears to be much longer than for the queens'-egg-larvæ under the care of queens alone, or under the care of queens and workers, or under the care of workers alone. Judging from data recorded from five groups of isolated workers that have been rearing their own progeny in my nests during ten months, I think these larvæ sometimes take more than two hundred days in their growth from egg to pupa.

The workers' eggs are about half as large as are the queens' eggs; the larvæ on issuing from the eggs are but half as large as those issuing from queens' eggs; the pupæ are also much smaller than are those of males produced from queens' eggs, and the adult males are dwarfs, being from four to five millimeters in length of body, without the wings.

A colony captured by me on July 13, 1900, lost its only queen on August 25. It was transferred from a Janet to a new, clean Fielde nest on September 6, and after that date had no communication with any other nest. Between the 17th of the following February and the 7th of June, 1901, twelve dwarf males were successively produced. No ants of any other sort were during four months produced in this queenless colony. All twelve of these dwarf males, with the utmost regularity, showed eyespots and ocelli of pale gray on the third day of pupal existence, and the color deepened to black on the fifth day. On the tenth day the

dorsal side of the abdomen became grayish, and on the twelfth day the head, thorax and abdomen were slate color, while the limbs remained white. Thereafter the color deepened to black, and in each of the twelve cases the pupa became an ant on the seventeenth day.

Four of these dwarf males, that remained during their natural lives with their worker-progenitors, lived respectively fifteen, thirty-two, thirty-four and forty-five days.

The food which the *Stenamma fulvum piceum* were seen to eat in captivity was, in the order of their apparent preference, fragments of flies, roaches, mealworms, beetles and spiders; morsels of sponge-cake, white bread moistened with sweetened water or white syrup; apple, banana, boiled sweet-potato; fat of boiled fresh beef; soft gum-drop, almond paste, pie crust, hickory nut and honey. They showed no lively interest in other than insect food of which they had been for some days deprived. They appeared to avoid all raw or cooked meats other than particles of fat. Their liking for a varied diet and their attention to unusual delicacies indicate a highly developed sense of taste.

Though the attitude ordinarily assumed in eating is that of standing on all six legs and lapping the food, I have twice seen an ant stand on four legs, using the front feet to hold an insect-egg to its mouth, suggesting the posture in which a squirrel commonly eats nuts.

The amount of food required to sustain life must be small. I isolated sixteen workers in groups in clean Petri cells, containing nothing but sponges that were frequently cleaned with ninety-five per cent. alcohol and then saturated with water. Of these ants one lived five days, five lived six days, two lived seven days, one lived eight days, three lived nine days, one lived twelve days, one sixteen days, one twenty-one days, and one thirty-four days without visible food. That these ants died from starvation and not from other cause was indicated by the control experiments in which other ants similarly placed, but with a supply of food, continued to live on for months. The ability of *Stenamma fulvum* to endure starvation is, however, exceeded by the less active *Formica fusca* and the sluggish *Ponera coarctata*, one of the former having lived in my Petri cell forty-one days, and one of the latter forty-three days, without visible food. *Formica sanguinea* shows lesser tenacity of

life, as none of several subject to the same experiment lived more than six days.

The *Stenamma fulvum piceum* also meet extreme cold with impunity. At about 50° F., or 10° C., they become sluggish, remaining almost or quite motionless in their usual attitudes. I froze a two-queen colony for twenty-four hours, the thermometer going down to 23° F., or 5° C. On gradually thawing the ants, all survived, including callows but two days old, and the frozen pupæ, larvæ and eggs developed perfectly later on. Another small colony was frozen continuously for five days, the thermometer going down to 15° F., or 10° C. The queen and all the workers survived thawing, but a fifth of the workers died soon after, and the queen, who had previously laid eggs almost daily for five months, laid no egg thereafter for eighteen days.

It is probable that these ants, being highly thermotactic, seek the deeper, warmer recesses of their nests in the ground in autumn, and there hibernate until the warmth of spring draws them toward the surface.

The color of these ants manifestly deepens with age. The newly hatched callows are translucent amber. The brown tint of the adult first begins to appear on the dorsal side of the largest segments of the abdomen. Some of the majors have already this beginning of brown coloration before they pass the pupa stage. The head, which is throughout life darker than the thorax, takes on color next after the abdomen. In three or four months the young worker has the color of an adult, but very old ants, queens as well as workers, attain deeper shades of brown with passing years. The males are fully colored, a glossy jet black, even before leaving the pupa stage.

I have not yet the data from which to draw conclusions concerning the longevity of queens and workers, though I have those in my nests that are certainly over one year old. The shorter-lived males have furnished me the following record relating to their longevity:

Longevity Table for 20 males, presumably the issue of queens' eggs.

a. Swarmed September 17 from roadside colony, isolated with queen of another colony in a Petri cell, lived . . . . . 5 days.

b. Swarmed September 17 from roadside colony, isolated with queen of another colony in a Petri cell, lived . . . . . 7 days.

c. Swarmed September 17 from roadside colony, isolated with queen of another colony in a Petri cell, lived . . . . . 13 "

d. Swarmed September 17 from roadside colony, isolated with queen of another colony in a Petri cell, lived . . . . . 20 "

e. Swarmed September 17 from roadside colony, isolated with queen of another colony in a Petri cell, lived . . . . . 20 "

f. Swarmed September 17 from roadside colony, isolated with queen of another colony in a Petri cell, lived . . . . . 102 "

g. Captured September 11 from nest in woods, isolated with queen of another colony, lived . . . 18 "

h. Captured September 11 from nest in woods, isolated with queen of another colony, lived . . . 19 "

i. Captured September 11 from nest in woods, isolated with queen of another colony, lived . . . . 19 "

j. Captured September 11 from nest in woods, isolated with queen of another colony, lived, ... 40 "

k. Hatched in Fielde ant-house, November 22, lived with his sister-workers, no queen, lived . . . 14 "

l. Hatched in Fielde ant-house, November 22, remained there with queen-mother and workers, lived . . 24 "

m. Hatched in Fielde ant-house, November 22, domiciled with sister-workers, no queen, lived . . 40 "

n. Hatched in Fielde ant-house, November 27, domiciled with sister-workers, lived . . . . . 42 "

o. Hatched in Fielde ant-house, November 27, remained there with mother-queen and workers, lived . . . . . 72 "

p. Hatched in Fielde ant-house, December 1, domiciled with sister-workers, no queen, lived . . . 87 "

q. Hatched in Fielde ant-house, December 1, remained there with mother-queen and workers, lived . 100 "

The king that lived longest, having been taken at the swarming, must have lived considerably more than 102 days, and his residence with a queen did not manifestly shorten his days.

The history of this little pair illustrates interesting traits of these ants. The two were taken from different colonies on a sunny morning after heavy rain, September 17, 1900. They were immediately placed by themselves in a Petri cell, and were at once

friendly. The courtship or honeymoon was distinguished by mutual devotion. The one was rarely beyond the touch of the other, and the satisfaction of the two in their companionship was apparently equal. If the queen moved the king usually followed. If the king failed in constancy of attention to her, the queen approached and by a side stroke of her antenna made him aware of herself. This queen was exceptional in retaining all her wings until after she deposited her first two eggs, on the 15th of November, two months after swarming. She had laid twenty-eight eggs before she lost the wings of one side, on December 7, and she laid many more before her last wing fell off in January.

From the time of first egg laying, the king and queen both watched over the eggs, one of them remaining on guard when the other went to the opposite side of the cell to eat. The king watched over the eggs in the absence of the queen, but he never lifted them nor carried them about as did the queen.

On the death of the king, December 28, after more than a hundred days of wedlock, as he lay prone on his back with outspread wings, the queen piled her twenty eggs upon him, and hung over the body persistently. On ensuing days I separated the body, the queen and the eggs, first by a distance of a half-inch, then of an inch, then of two inches, then of three inches, and in a few hours after each separation the queen had brought the body and the eggs again together and stood with her head lowered over them, her mouth usually near the king's mouth. On the fifth day after his death, I moved his body to the opposite side of the cell, and separated it from the eggs by an intricate route between the sponges. The distracted queen at once set out in search of her treasures, and in her efforts during the next two days to bring the body and the eggs together, she so scattered the eggs that, fearing the loss of them, I took out the shriveled body, collected the eggs, and left the queen alone with them in a cleaned cell.

Two males, one the issue of a workers' egg, the other of a queens' egg, were later on introduced separately into her cell, and were killed and dismembered by her.

The queen continued to lay eggs, and the eggs at frequent intervals produced larvæ, but this queen was evidently unable to feed her young larvæ, and I had no workers of her own colony to offer her. Up to the end of May, 1901, she continued to lay

eggs and the young larvæ continued to perish. Meantime two of her eggs, given on January 31 to the care of three alien workers living in a cell by themselves, had produced one queen and one king.

After four months of failure had sufficiently shown the inability of this queen to alone rear her larvæ, I attempted to reconcile her to alien helpers, putting in at different times from other colonies five young workers of ages varying from a few days to a few hours, and all were killed by her, or were removed on account of endangering her life. One callow minor, after having been nine days in the cell with the queen, nipped her so viciously and tenaciously that I could release her only by decapitating her enemy. The mutual fear and hostility of the queen and the alien workers, with the common desire to possess and care for the eggs, always resulted in the scattering and eventual loss of the eggs.

However, two other alien workers, one minor and one minim, introduced into the cell when but a few hours old, after several days' residence with the queen and numerous timid tentative approaches, perfectly affiliated with her. She laid no eggs thereafter until the ninth day in an eggless cell, and then she continued to lay an egg or two daily, to be picked up and taken care of by her adopted callows. Two white pupæ were also introduced into the eggless cell and there became ants, and in June the long solitary and childless queen had four devoted workers caring for her own young larvæ.

Ants have great aptitude in the recognition of their kin of the same colony. A colony found in the woods just previous to its swarming, on September 7, 1900, was divided and placed in two nests, *C–e* and *C–d*, each with one queen. After eight months of separation, ants brought together from the two nests perfectly and immediately affiliated.

Sister-queens of this colony, kept apart in Petri cells with a few workers to June 17, 1901, were after nine months' separation from their colony, received back with distrust. They were nabbed and held by the workers, but they were themselves quiescent. The attacks of the workers were hesitating and tentative, and after they had passed their antennæ over the whole body of the visiting queen, they left her alone. After a few hours in the nest, she was beside her former associate, and the workers were gathered around

the two in the manner usual with colonies that have two esteemed queens.

That the recognition of the ants is not personal is proven by the following fact: Workers hatched in nest *C–e* during the first half of November, 1900, were isolated in nest *A–a*, while workers hatched in nest *C–d* during the same period of time were isolated in nest *A–b*. The two sections *C–e* and *C–d* had each its own queen, workers and young, and there was no communication between the two nests after the division of the original colony on September 7. Between nests *A–a* and *A–b* there was no communication, and these two nests contained workers only. The workers of nest *A–a* had never during their active lives met those in *A–b* nest until six months after they all became ants, when I put them together in a Petri cell. There was at first an exhibition of mutual distrust, and even of animosity, which gradually disappeared when the antennæ had been passed over the bodies of the strangers, and in a half-hour all were amicably congregated in a single group.

These ants have a habit of bringing their bodies to a low level, stretching their legs wide asunder, and creeping slowly up to an object of suspicion, in a manner that is quite catlike in its stealthiness; and this mode of approaching was often used toward the strangers, after the antennæ had once touched.

I also transferred pupæ from *C–d* nest to the care of queens of other colonies, and left them there in the care of aliens until they became ants and reached the age of about sixteen days. On returning these callows to the *C–d* nest, which they had left as pupæ, they exhibited great fear of their relatives and hosts, sought to stay in parts of the nest most remote from the resident community, hid themselves, and showed all the trepidation usual in ants that are put into a nest of aliens. On the other hand, the resident ants made no unfriendly demonstrations toward the newcomers, and after these callows were forced into association with them by confinement with a few of the adults in a small space, the callows lost their fears and thereafter mingled freely and happily with all in the nest. In less than a day they were incorporated in the community where they accomplished their larval career.

Callows of the same stock, *C–d*, of the same age and the same

rearing as the above, were introduced the same day into an absolutely alien community, *B–b*, were instantly attacked, and were dismembered and then fed to the larvæ or eaten by the ants.

Four adult workers, two majors and two minors, that I took in August, 1900, from an apple-core by the roadside and isolated in a Petri cell, on December 4 killed two alien callows that had just come from the pupa-stage in *C–d* nest. The next day they received three amber pupæ from *C–d* nest, and one of these pupæ that same day became an ant, and of it the adult ants appeared to be very fond. On the 6th and 8th of December they killed two of its sisters, introduced when but a few hours old into their cell. On December 9, when the callow hatched in this cell was four days old, I put in an ant only seven hours old, also from the *C–d* nest. The four-day-old callow was the first to meet the baby ant in the Petri cell. It licked its junior from end to end, and when the adults repeatedly approached and snapped with their mandibles at the latest comer, the older callow stood over and appeared to wittingly protect the younger. It then picked up the baby ant, which was a minim quite as large as itself, and carried it into the shade of the sponge where two pupæ were attended by the adult ants. There it stood between the adults and the baby, giving attention alternately to it and to the pupæ, and often touching the adults with its antennæ, until after many minutes the adults left all to its care. From that time the adults showed no further hostility toward the younger minim, and it continued to live in that cell.

While it is generally true that *Stenamma fulvum piceum* will capture and care for the eggs, larvæ and pupæ of alien colonies, they do not invariably rear these to adult life.

A queen alone will not usually accept any worker from an alien colony, but persistent effort may induce her to accept a very young worker.

A queen alone with her eggs will not usually accept alien pupæ. She carries them away and casts them in her rubbish heap. But if alien larvæ are introduced she will accept them, and then she will later on accept pupæ from the same stock. She will at any time accept alien eggs.

Queens assisted by numerous workers will receive alien eggs, larvæ or pupæ, separately or together, the workers assuming immediate charge of them.

I have seen queenless workers break up and feed alien pupæ to the larvæ they were rearing, but when they had no larvæ they took excellent care of pupæ from the same alien stock. As one pupa will furnish an ample meal to a great number of larvæ, there may be much economy in thus utilizing an alien pupa that appears unseasonably in their nursery.

An explanation of the somewhat erratic behavior of the ants toward alien young will be suggested in a subsequent paragraph.

In many of the experiments made to test the power of these ants in recognizing those of their own colony, I used a small number of ants in each cell, and, without marking the ants, I could, by choosing those of one shade from one colony and those of another shade from another colony, always identify the colony to which any ant used in the experiment had originally belonged, and could invariably return her to her own.

The power of *Stenamma fulvum piceum* to recognize another of her own colony is not destroyed by freezing and thawing either one or both of the individuals.

Neither is it destroyed by merging one or both for an instant in alcohol, in diluted oil of anise-seed or of bergamot, in tincture of valerian or of asafœtida. The adult workers will survive dipping in eighty per cent. alcohol or in the above-mentioned oils and tinctures duly diluted. On returning the dipped workers to their colony they are not attacked as are aliens, though they may be for a time avoided, and on recovering from the bath they join their comrades in the common vocations of the nest.

I repeated one of the experiments of Bethe and obtained with my ants results similar to his. When I mashed ants of colony *C–e* and with the juices thus obtained smeared ants of the alien colony *B–b*, the *C–e* colony received the smeared ants without hostility, and the smeared ants exhibited the trepidation usual at finding themselves in an alien nest. Likewise, ants from the *C–e* colony, freshly smeared with the juices of *B–b* ants, were not attacked in the *B–b* nest, but they were evidently terrified in being there.

I then smeared a small number of *B–b* ants with the juices of *C–e* ants, and put them into a new Petri cell with an equal number of unsmeared *C–e* ants; and I smeared a small number of *C–e* ants with the juices of *B–b* ants and put them into a new Petri

cell with an equal number of unsmeared *B–b* ants. In no case did the unsmeared ants attack the ants that had been merged in the juices of their kin; but the smeared ants attacked the unsmeared ants as they commonly attacked aliens. The smeared ants never attacked each other.

After a worker had been smeared in the juices of ants of an alien colony and then isolated for about thirty hours it was returned to its colony, and every worker that touched it with the antennæ started back in alarm, but it was not attacked nor harmed. The juices probably wore off gradually, since smeared workers returned to their colony after one week of isolation were received with no sign of distrust.

A queen that had for over three months peacefully shared the cell and labors of a sister-queen and five workers was smeared with the juices of aliens and at once returned to the cell. She was immediately attacked by the workers as if she were an alien. She evinced dread and submission in the usual manner of these ants by cowering low, tightly shutting her mandibles, folding her antennæ and holding them close down upon her head. Three workers together attacked her, but the attacks were intermittent, and she soon crept up to her sister-queen. The queen prodded he curiously with the ends of the antennæ and showed no animosity. Then a worker came and nabbed her in places and licked her in places, as though she was a composite of alien and kin. She was kept aloof from the group for a day or two and then resumed without harm her former associations.

Workers merged in alien juices were likewise attacked on being restored to their kin, but the attacks were not persistent and none were slain. The losses of life or limbs all occurred through the attacks of the smeared workers upon the aliens, among whom they were as wolves in sheep's clothing. The smeared ants, in spite of their disguise, must have retained some evidences of their lineage which protected them from extreme violence.

When two parties, each consisting of several workers that had been merged in the juices of the kin of the other party, were placed together in a new Petri cell, there were no violent attacks from either side during the first two or three days. A tendency to congregate according to colony showed itself from the beginning, but by keeping the cell clean and preventing separate settlement of

the two parties I secured the safety of both for eight days. When I put in larvæ there was strife for its possession, and at the end of three weeks the only survivor of one party defended the larvæ against the sole survivor of the other party that, with but five legs and a single antenna, still made stealthy approaches toward the coveted young.

My observations of *Stenamma fulvum piceum* sustain the usual view that ants have an inherent and hereditary odor, or something akin to odor, whereby they are identified as friends or enemies, and that they impart this odor to places which they frequent. All the phenomena that I have observed in the lives of *Stenamma fulvum piceum* indicate that the distinctive odor may appear first in the larvæ, and a little less faintly in the pupæ; that it intensifies with age as does the color; that the sensitivity of the queen to this odor is greater than is that of the workers; that any distinctive odor to which an ant is accustomed and with which it associates security and satisfaction is attractive to it, while ant-odors to which it is unaccustomed excite alarm and hostility in proportion to their strangeness. For such causes, ants that have come from the eggs of colony *M* and in their pupa-stage were transferred to colony *N*, while they affiliate perfectly with the *N* ants that they live among, quickly recognize the odor of the *M* ants because it is their own. As to the origin of the distinctive colony odor, it appears possible that it may be traced to a king.

Among *Stenamma fulvum pieeum* there are differences in individual traits. Some are more truculent than are others of their sex, age and size; or are more assiduous in their attention to the young; or more devoted to the queen or the males; or more gregarious in habit; or more attached to the home; or more hostile toward aliens. Every characteristic of a typical *Stenamma fulvum piceum* appears strongly in certain individuals and is comparatively weak in others.

The increasing tameness of my captive ants has been observable. After some months of acquaintance, these Myrmicid ants have wholly ceased to sting me when I handle them.

So domesticated have they become in their artificial nests that they rarely run outside their houses when uncovered, and the accustomed routine of cleaning their dwellings agitates them scarcely at all.